Korean National Program Expedition Confirms Rich Gas Hydrate Deposits in the Ulleung Basin, East Sea

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November 2007 marked the successful completion of South Korea's first large-scale gas hydrate exploration and drilling expedition in the East Sea: Ulleung Basin Gas Hydrate Expedition 1 (UBGH1), which successfully explored and recovered gas-hydrate-bearing sediments at three different locations in the Ulleung Basin. Expedition UBGH1 sailed 57 days in two legs aboard the multipurpose offshore support vessel *REM Etive*, which had been converted to a drilling ship by Fugro Seacore using the heave-compensated R100 portable drill rig (Figure 1). The Korea National Oil Corporation (KNOC) and Korea Gas Corporation (KOGAS) contracted Fugro to supply drilling, wireline logging, coring and associated services for Expedition UBGH1, while other companies including Schlumberger and Geotek provided Logging While Drilling (LWD) and core analysis services respectively. Technical decisions directing the scientific aspects of the work were made by the Korea Gas Hydrate R&D Organization and the Korea Institute of Geoscience and Mineral Resources (KIGAM).

Leg 1 of the expedition investigated five "type" locations in the Ulleung Basin (Figure 2), which were selected as representative of the basin based on pre-expedition 3-D seismic evaluations. Each of these sites was logged using the Schlumberger LWD suite of tools; in addition, 14 surface cores as well as many hours of camera surveys were collected using the *REM Etive's* remotely operated vehicles. The LWD data was used to select the three "type" locations most likely to contain gas hydrate for subsequent drilling and sampling on Leg 2. The second Leg lasted five weeks and entailed the drilling and coring of the three sites, where significant gas-hydrate-bearing reservoirs were documented up to 150 meters below the seafloor and at water depths between 1800 to 2100 meters.

Figure 1: The REM Etive *in dock at Busan, Korea, with the R100 drill rig amidships and laboratory containers aft.*

Shipboard Data and Samples Collected

During UBGH1 Leg 2, a total of 38 conventional cores were recovered and 15 successful pressure cores were taken (75% success rate). Conventional and pressure cores were recovered downhole using several wireline coring tools: i) a long piston corer (Fugro Hydraulic Piston Corer) which takes 7.5 meter cores; ii) a short hammer corer (Fugro Corer), which takes 3 meter cores; and iii) the Fugro Pressure Corer (Figure 3) and Fugro Rotary Pressure Corer which take 1 meter long cores at in situ pressures. One of the three sites also had wireline logs run with a suite of high precision slimline tools, including sensors for natural gamma, gamma density, neutron porosity, electrical resistivity, hole diameter and temperature.

Shipboard core analyses targeted the identification and quantification of gas hydrate within the sediment. Infrared thermal imaging was used to determine gas hydrate locations in all conventional cores; 18 samples containing gas hydrate were rapidly frozen in liquid nitrogen. The thermal data were used to identify samples for porewater analysis (for gas hydrate quantification; 249 samples) and gas analysis (for potential gas hydrate composition; 53 samples). Selected core sections were also split onboard for shipboard sedimentological description; 70 smear slides were described on board ship.

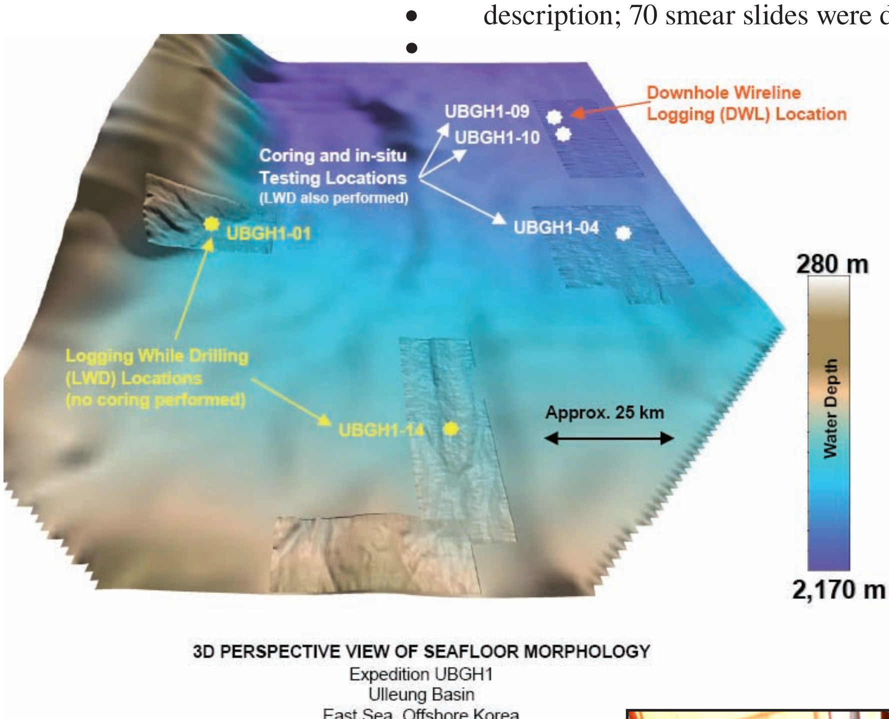

Figure 2: Study sites in the Ulleung Basin, a back-arc basin off the east coast of South Korea.

Figure 3: Drill floor on board REM Etive*, with the FPC being loaded into the drillstring prior to lowering and coring.*

All pressure cores were analyzed under in situ pressure using the Geotek MSCL-P (Pressure Multi-Sensor Core Logger) to rapidly identify gas hydrate and measure gas hydrate-sediment properties under pressure. Gas hydrate may be visible in X-ray images (Figure 4) or gamma density profiles as low-density structures, or identified by high acoustic velocities. After MSCL-P analysis, seven of the pressure cores were stored for further analysis on shore; the remaining eight cores were subjected to controlled depressurization experiments to quantify the methane concentration and thus the gas hydrate saturation within the core. Once depressurized, pressure cores were sampled for porewater analysis to determine porewater freshening from gas hydrate dissociation.

Figure 4: An X-ray of a pressure core collected on Expedition UBGH1 showing gas hydrate in veins and layers. Gas hydrate was present at all three locations.

Preliminary Findings

The sediments from the three locations drilled and cored during UBGH1 were all deposited in sea-level controlled slope/basin environments; the finer sediments were a mix of terrigenous and pelagic materials, with coarser materials deposited by debris flows or turbidity currents. The dominant sediments were siliceous and calcareous clays, however coarser-grained sand and silt beds, centimeters to meters thick, were also present (Figure 5). Gas hydrate was detected at all three sites in both the clay matrix, as veins and layers, and as pore-filling material within the silty/sandy layers (Figure 6). At one site, a 130-meter-thick gas-hydrate-bearing sedimentary interval of interbedded sands and clays was penetrated, which is one of the thickest gas-hydrate-bearing intervals to be documented worldwide. Another 100-meter-thick gas-hydrate-bearing interval was also discovered at another location. Methane was the predominant gas within core voids as well as in gas hydrate at all three sites; ethane was 0.3% or less of most gas samples (maximum

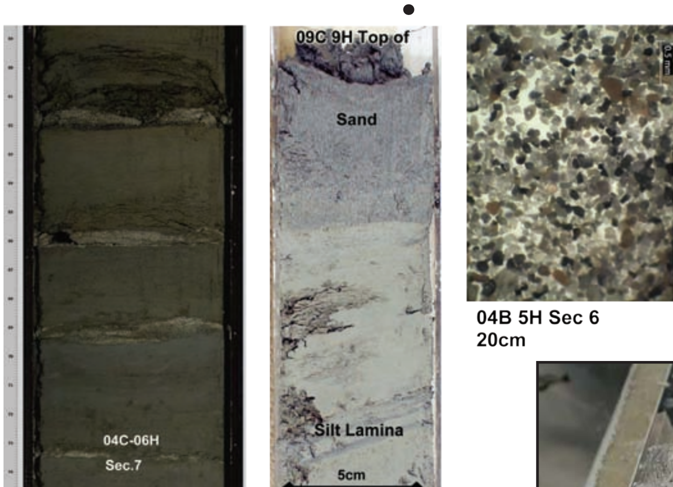

Figure 5: Images of interbedded silts and sands in a clay matrix, along with photomicrograph of coarse fraction. The coarser-grained materials were mostly composed of quartz, but foraminifera and volcanic glass shards were also present.

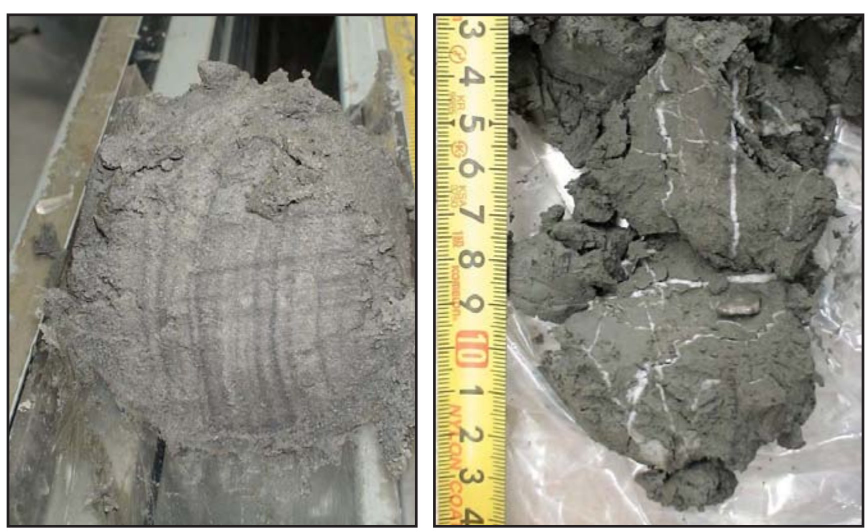

Figure 6: Gas hydrate present in clay material as veins, displacing sedimentary grains, and as a pore-filling matrix within sandy layers.

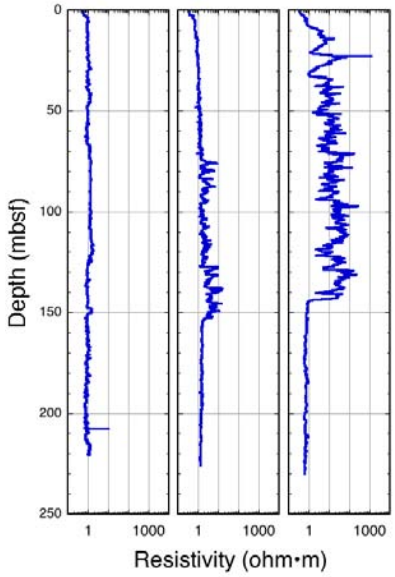

Figure 7: LWD electrical resistivity from the three "type" locations drilled, showing resistivity profiles differing by orders of magnitude. Gas hydrate was present at all three locations

ethane concentration 1%, in hydrate-bound gas). Quantification of gas hydrate from porewater freshening analysis showed that gas-hydrate-bearing sand layers contained an average of 30% gas hydrate by pore volume. The highest gas hydrate saturation from analysis of pressure cores, which average over a one-meter interval, was 23% gas hydrate by pore volume. While the overall magnitude of the electrical resistivity logs (Figure 7) correlated loosely with the overall average gas hydrate saturation for the different sites, there was no obvious quantitative relationship between the two data sets.

Implications and next steps

The five "type" locations drilled in the Ulleung Basin (three of which were cored) will now allow extrapolation of gas hydrate probability to other sites in the Ulleung Basin that have seismic data. The thick gas hydrate accumulation discovered at one of the locations is similar in many ways to that found in the Krishna-Godavari Basin on Indian National Gas Hydrate Program Expedition 1, with many grain-displacing gas hydrate veins in clay, but there are also similarities to the preferential distribution of hydrate in sands found in the interbedded sands and clays drilled on Integrated Ocean Drilling Program Expedition 311 at the Cascadia Margin.

Post-expedition studies are ongoing and include continued interpretation and evaluation of the numerous datasets collected while at sea, detailed sedimentological description of split-core sections and analyses of sediment sub-samples, testing of frozen gas-hydrate-bearing sediments, and analysis of gas and porewater samples collected shipboard. The postcruise analysis of the pressure cores was recently completed (to be the subject of a future article in *Fire in the Ice*), though one core remains stored under pressure for future analysis.

Members of the UBGH1 Korean scientific party with a sample of massive gas hydrate.